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The relationship between Algebra Nation usage and highstakes test performance for struggling students

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The Relationship Between Usage of the Algebra Nation Tutoring Program and Test Performance for Students Who Fail and Retake the End-of-Course Exam

Abstract

Although the use of technology in the K12 classroom has been shown to have a positive impact, research on the use of open education resources (OER) is relatively limited, especially research with a focus on low-achieving students. Using secondary data, the present study examines the relationship between usage of Algebra Nation, a popular self-guided system that provided instructional videos and practice problems, and the performance of students who had failed the state-administered Algebra I end-of-course (EOC) assessment the previous year. Indicators of usage of Algebra Nation consisted of logins, video views, and practice questions answered in the Test Yourself module. Path analyses and logistic regressions were used to evaluate relationships between Algebra Nation usage indicators and algebra scores, controlling for number of absences, free/reduced lunch eligibility, Hispanic/Latino origin, race and gender. The results indicate that higher levels of logins, video views and practice questions answered were related to higher scores when the students re-took the assessment. Logins and practice questions were also related to increases in odds of passing the Algebra I EOC assessment, but not video views. The results suggest that there may be benefits to technology use in the form of an OER adopted by students and teachers on an informal basis, and link self-regulated learning strategies to student achievement.

The relationship between Algebra Nation usage and highstakes test performance for struggling students

Recent research suggests that educational technology has become thoroughly integrated into K12 classrooms. Students and teachers no longer make a distinction between learning experiences that do or do not utilize technology, and most students now have access to the Internet at home and at school (NAEP, 2015; National Forum on Education Statistics, 2015). Education technology is now recognized by educators, parents, and policy makers for its potential to improve student learning outcomes. Recent meta-analyses have documented a generally positive effect associated with the use of education technology in the classroom (Cheong & Slavin, 2013; Kulik & Fletcher, 2016; Steenbergen-Hu & Cooper, 2013).

As technology-based resources have become increasingly established in the K12 classroom, there has been a greater consideration given to the nature of the technology, referring to its source, design and how it is intended to be used. Cheung and Slavin (2013) considered three types of education technology: supplemental computer-based resources to provide students with additional practice opportunities, computer-based learning management systems designed to assess and track student progress, and comprehensive models in which learning activities that take place at the computer are embedded into a theory-based curriculum. Reviews conducted by Steenbergen-Hu and Cooper (2013b) and Kulik and Fletcher (2016) specifically considered studies of intelligent tutoring systems, referring to computer-based systems that continually adapt instruction to students' individual strengths and weaknesses (Koedinger et al., 1997). These

systems have typically been designed and developed by educational publishers or researchers based on theories of how people learn. Most of these types of resources also include clear guidelines for how the technology is to be used and are often supported by professional development training for teachers. Often, states or districts specify what resources may be used and there is a formal review and adoption process for technology products (Means et al., 2016). An alternative form of technology includes "open educational resources" (OERs; UNESCO & Commonwealth of Learning, 2011). Many are user-generated, shared freely on the web, and available for use on an ad hoc basis. Such resources differ from the education technology platforms considered by Cheung and Slavin (2013), Steenbergen-Hu and Cooper (2013b) and Kulik and Fletcher (2016) in that they are not necessarily grounded in theories of learning, used as part of a comprehensive curriculum, or accompanied by professional development for instructors. For example, the popular Khan Academy website began in 2006 as a collection of screen-cast videos made by Sal Khan who posted the videos on YouTube to share solutions to math problems to a young relative who lived across the country (Thompson, 2011). The site quickly attracted users who visited on an informal, drop-in basis. The site now has expanded to include instructional videos on hundreds of topics and is visited by millions of viewers per month (Phillips & Cohen, 2015).

OERs have proliferated in the last 15 years, and there has been a corresponding increase in interest in knowing how they are being used and what their impact is on students (Means, Anderson & Thomas, 2013; Watson, Pape, Murin, Gemin & Vashaw, 2014). The use of OERs is driven informally by students and teachers themselves rather than being a formal part of a curriculum (Olcott Jr., 2012). There is a current gap in the literature on strategies to support students to use OER, but there have been attempts to provide a framework for development of

strategies (Kim, 2018). In order to design strategies for students to use OER, it is critical to investigate their impact on student achievement. Because the use of OERs is often casual and widely varied across users, researchers are adopting new approaches to explore their impact (Koedinger et al., 2015). One strategy is to use digital records documenting students' use of an open resource and then investigating variations in learning outcomes in relation to use (Koedinger et al., 2015, 2016; Means et al., 2013). Although this approach will not support causal conclusions, it is an initial step towards assessing if students who have used an OER may have received some corresponding benefit from it. For example, in the case of Khan Academy, researchers used records of student logins to identify frequent and less frequent users of the SAT assessment practice resources. Frequent users achieved higher scores on the SAT assessment than would have been predicted on the basis of their PSAT score (Murphy, Gallagher, Krumm, Mislevy & Hafter, 2014). Although conclusions were limited by the lack of a comparison group and by the focus on high achieving students, the initial evidence was promising enough to support more traditional experimental research incorporating random assignment (currently underway; see Schneider & Hauk, 2014).

Systematic evaluations of the relationship between the use of OERs for the K12 classroom and student achievement are starting to appear in the literature. For example, Roschelle, Feng, Murphy and Mason (2016) conducted a cluster randomized trial of the ASSISTments platform, which provides online homework assistance and feedback to students and reports to teachers. They a significant difference of 0.18 standard deviations in the mathematics performance of students in schools using ASSISTments as compared to schools using traditional homework. The present study contributes to this literature by reporting the initial results associated with a recent example of an OER widely-used in the state of Florida:

Algebra Nation (AN). AN is a tutoring system designed to prepare students for the state-administered Algebra I end-of-course assessment (EOC), which is a high-stakes test in Florida required for high school graduation. AN was originally launched in 2013 as a free stand-alone website by a partnership between a university research center and a small tutoring business. Although not strictly an OER because it was not released under an open license (UNESCO & Commonwealth of Learning, 2011), AN shares the following OER characteristics: 1) Students have autonomy to use it away from formal curricula; 2) It allows self-paced/regulated learning; 3) It is available on an ad-hoc basis. Also, AN functions as an OER within Florida because every student and teacher has free access to it. AN quickly attracted users through word-of-mouth and by 2016, records in the AN database documented that there were some users in every district in the state. However, usage patterns varied widely, making it difficult to determine whether AN use was actually associated with increased assessment scores as intended by the developers.

AN includes instructional videos and practice problems that resemble those on the actual EOC assessment. Students can also download a workbook of practice problems from AN, and the videos address solving problems in the workbook. Moreover, teachers are able to request paper workbooks for their students that contain all the practice problems. The platform has some similarities to the original Khan Academy in that it is self-guided and freely available to any student or teacher in the state. AN has about 100 videos with scope and sequence aligned with the Florida standards, with about 10 videos for each of 9 algebra topics. There are multiple versions of each video with different tutors, with different durations and levels of detail that the content is covered. The differences in depth of coverage is highlighted by a sliding bar varying from “review” to “in-depth” next to the tutor’s name and picture. Therefore, students can choose tutors with the presentation style that they find most appealing. The “Test Yourself” practice

module is designed to look like the actual EOC assessment, including an integrated calculator and clock/timer. Also, there is an item pool with about 100 items for each of nine algebra topics. The topics covered by AN are: 1) Expressions, 2) Equations and inequalities, 3) Introduction to functions, 4) Linear equations, functions and inequalities, 5) quadratic functions, 6) Exponential functions, 7) Summary of functions, 8) One-variable statistics, 9) Two-variable statistics. The items include multiple formats: equation response, numeric fill in the blank, drop-down select, multi-select, and multiple choice. There are both one-step and multiple-step items and some have multiple solution paths. When students select to take the Test Yourself practice module for one algebra topic, the system randomly selects 10 items to administer. For each item, there is a solution video, and a review video for the topic. There is a pre-algebra remediation tool available with a separate set of videos and assessment questions. Students have access to the Algebra Wall, which is a discussion forum monitored by tutors who assist students with their questions. However, AN is different from intelligent tutoring systems in that it does not prompt students for steps or provide hints. Also, the process of navigation through the system is completely driven by the student. When the student answers a question incorrectly, it only points out that the answer is incorrect and provides the solution video and a review video of the concepts, but it does not provide an elaboration on the reasons for an answer being incorrect. Also, practice questions that have multiple steps are graded as correct or incorrect, and there is no partial credit or feedback on which steps were incorrect.

Initial research (Leite, 2017; Mitten, Collier & Leite, 2016) provided preliminary evidence that the use of AN in schools is associated with increased mean EOC assessment scores and increased passing rates. More specifically, Leite (2017, p.143) performed a generalized propensity score analysis of school level data to estimate the effects of number of AN logins per

examinee in each school on the school's mean score on the EOC assessment. He found a small but statistically significant effect, with an increase in 10% in logins per examinee corresponding to predicted increase in mean EOC scores of 0.063. Mitten, Collier & Leite (2016) performed a latent class analysis of six school-level indicators of AN usage: 1) average number of student logins, 2) average number of student videos viewed, 3) average number of teacher logins, (4) average number of teacher videos viewed, 5) ratio of total videos viewed and the number of ordered workbooks, 6) ratio of total number of logins and the numbered of ordered workbooks. They found that schools in the sample could be clustered into 3 classes of different level of usage of AN, and that schools in classes with higher level of usage also had mean EOC assessment scores and higher passing rates.

The current study contains the first student-level analysis to focus specifically on re-takers. In contrast to the initial research on Khan Academy which focused on high-achieving, college-bound students, here the focus was on those students most at risk of failure. Successful completion of high school algebra courses has been identified as an important milestone for college readiness, college enrollment, attainment of a college degree and future employment. Unfortunately, algebra courses typically have a high failure rate. Failure means that many students must retake algebra (Fong, Jaquet & Finkelstein, 2014). However, the prospects for re-takers are grim because when students fail Algebra once, they are likely to fail it again (Ham & Walker, 1999, Helfand, 2006; Waterman, 2010). In 2017, 73% of students who took the Florida EOC assessment for a second time (or more) failed again.

The need to repeat algebra is costly for the education system and for the student (Fong, Jaquet, & Finkelstein, 2014). Recent research suggests that educational technology could potentially be an effective and cost-efficient approach to algebra instruction (Bishop, 2006; Jung,

2003; Taplin, Ross, Kerr & Brown, 2013). Studies of online programs have shown benefits relative to traditional classroom instruction (Cavanaugh, Gillan, Bosnick, Hess & Scott, 2008; Hagerty & Smith, 2005; Heid & Blume, 2008; Heppen et al., 2012; Jaciw, Megan & Boya, 2012; Pane, Griffin, McCaffrey & Karam, 2014; Patrick, & Powell, 2009; Rakes, Valentine, McGatha & Ronau, 2010; Roschelle et al., 2010; Shaw, Jean & Peck, 1997). However, this research generally considered the impact of traditional technology aligned with a district curriculum, rather than OERs whose usage was determined by students and teachers on an informal basis. Also, in the case of students who have already failed algebra once or more and are therefore at high risk for future failure, the potential of educational technology is less clear. One study of credit recovery courses found that students who took a face-to-face course were more successful than those who took the online version (Heppen et al., 2016). Thus, it was not clear that casual use of an OER, however popular, would actually be associated with a detectable effect in algebra achievement of students who were struggling with the material.

The goal of the present study is to evaluate the relationships between usage of resources within AN by students with a history of failure on the EOC assessment and the scores these students obtain when they re-take the assessment. The conceptual model for the study is shown in Figure 1. A similar analytic strategy to that used in the case of Khan Academy (Murphy, Gallagher, Krumm, Mislevy & Hafter, 2014) was adopted: students in the AN database who had already failed the assessment once were identified, records of their use of AN were compiled, and relationships between AN use and EOC assessment scores were estimated. The analysis also included an investigation into the specific activities (i.e., watching videos, completing practice problems) within the AN platform that appeared to be most helpful. Based on prior work showing greater benefits of active practice, one might expect that doing practice problems would

have a stronger positive relationship with algebra scores compared to viewing instructional videos (Koedinger et al., 2016). Problem-solving practice benefits the learner by providing feedback and also appears to be a more efficient use of study time than viewing videos (Koedinger et al., 2015). However, evidence to support the "do-er" effect was found in studies of college students and those enrolled in college-level MOOCs, that is, students who may be assumed to have some level of motivation to learn as well as reasonable study skills. It was not clear whether a similar benefit of practice would be observed in a sample of very low-achieving students who were facing the risk of not qualifying for high school graduation.

INSERT FIGURE 1 ABOUT HERE

Research Questions

1. For the students who failed the EOC assessment in 2014/2015, was there a relationship between usage of the Algebra Nation system in 2014/2015 and the students' scores?
2. For the students who failed the EOC assessment in 2014/2015, does higher usage of the Algebra Nation system in 2015/2016 predict higher scores and passing rates when they retook the EOC assessment in 2015/2016?
3. For the students who failed the Algebra EOC assessment in 2014/2015, do video views and completion of practice problems in the AN platform have different

relationships with student scores and passing rates when they retook the EOC assessment in 2015/2016?

For the first research question, the hypothesis is that even though all students in the sample failed the EOC assessment in 2014/2015, the students who used Algebra Nation more frequently performed better than those that used it less frequently, after controlling for established academic risk factors (i.e., free/reduced lunch eligibility, days absent) and demographic factors (i.e., ethnicity, Hispanic origin, and gender). For the second research question, the hypothesis is that using AN more frequently in 2015/2016 is associated with re-takers obtaining higher EOC assessment scores and higher passing rates, controlling for the students' 2014/2015 EOC score, free/reduced lunch eligibility, days absence, ethnicity, Hispanic origin, and gender. For the third research question, the hypothesis is that completion of practice problems will have stronger associations with EOC assessment scores in both 2014/2015 and 2015/2016 than video views.

Method

Sample

The sample for this study included all students in Florida public schools who satisfied the following conditions: (a) they took the EOC assessment for the first time in 2014-2015 and did not obtain a passing score; (b) they logged into Algebra Nation at least once in 2014-2015; and (c) they re-took the assessment in 2015/2016. The total sample size was 3,987 and included 7th to 11th grade students. The frequencies and percentages by grade level, gender, race, ethnicity and free/reduced lunch eligibility are shown in Table 1. The re-takers included in this study were more likely to be not-white (48%), eligible for free/reduced lunch (79%) and of Hispanic/Latino origin (32%) as compared to students taking the EOC assessment for the first time in 2015-2016

(34% not-white, 58% eligible for free/reduced lunch, 29% Hispanic/Latino origin). The proportion of students who were female was similar for re-takers and first-time-takers (55%).

Data Sources

Two datasets were combined for this analysis. The indicators of usage were obtained from Study Edge, the developer of the AN platform. The EOC assessment scores and demographic information of students were obtained from the Florida Department of Education. The combined dataset contained observations across two years (2014/2015 and 2015/2016) for each student. Students were clustered in 403 schools in the 2014/2015 school year, and 339 schools in the 2015/2016 school year. The average number of students who failed the EOC assessment per sampled school was 9.89.

Measures

Data about students' usage of AN during the school year, as indicated by the total number of logins, video views, and use of the Test Yourself practice module, was provided by the AN platform developer. Each usage indicator was binned into one of three frequency categories: fewer than five logins/video views/Test Yourself question responses, between five and 30 logins/video views/Test Yourself question responses, and more than 30 logins/video views/Test Yourself question responses. This categorization of the activity counts was performed because the total counts of usage were strongly positively skewed and non-linearly related to the outcome. To maintain evidence of construct validity for the usage indicators in this study, the boundaries of the categories were chosen in consultation with the AN development team to reflect students that may have looked at AN but did not use it in a meaningful way (i.e., fewer than five usage indicators), students who had moderate engagement with AN (i.e., between five

and 30 uses), and frequent users (i.e. more than 30 counts). Sample sizes for the use categories are included in Table 1.

Multiple demographic variables were obtained from the Florida Department of Education and matched by student ID to the AN data system. The specific demographic variables were the number of absences in each of the 2014/2015 and 2015/2016 school years, free/reduced lunch status as a proxy for socioeconomic status, gender, white race, and Hispanic/Latino origin of students.

Algebra Scores. The outcome measure was the student's score on the EOC assessment at the end of each of the two school years (2014/2015 and 2015/2016). The EOC assessment is a high-stakes standardized test administered in Florida to all students enrolled in algebra courses aligned with the Florida standards, such as Algebra I and Algebra I Honors. Students are required to obtain a specific score to pass the test and graduate from high school. The passing score is determined by Florida's State Board of Education. The test is a computer-based assessment that includes both multiple choice and fill-in responses (Florida Department of Education, 2018).

Data preparation

Data from different sources were aligned and then identifying information was removed before the dataset was made available for the analysis. The dataset had missing values in the students' demographic information and algebra scores. Initially, missing values were dealt with using listwise deletion by removing students who had missing EOC scores in 2014/2015 and 2015/2016. Then, the dataset was filtered to obtain students who failed the EOC assessment by removing students who had scores equal to or greater than 497 (the cut score to pass the assessment) in 2014/2015. Because demographic variables used in this study were time-

invariant, except the days-absent variable, remaining missing values in these variables were handled by replacing missing information in the 2015/2016 year with available information in the 2014/2015 year.

INSERT TABLE 1 ABOUT HERE

Analysis

We used two path analysis models and two logistic regression models to address the research questions. We created a path analysis model including AN login categories as predictors of EOC assessment scores, and another path analysis model with both categories of video views and Test Yourself module usage as predictors. Separate path analysis models were used because video views and Test Yourself module usage were expected to fully mediate the relationship between logins and the outcome, so including all indicators of usage in the same model would remove the relationships between logins and algebra scores. The implication of not including logins in the models that included video views and Test Yourself module usage is that if two students watched the same number of videos and responded to the same number of Test Yourself module questions, they were considered to have the same level of AN usage despite possible differences in the number of times they logged in to AN. The path analysis model for login categories as predictors of algebra scores was defined as:

$$Y_{1i} = \beta_{10} + \beta_{11}L_{11i} + \beta_{12}L_{12i} + \beta_{13}A_{1i} + \beta_{14}G_i + \beta_{15}M_i + \beta_{16}F_i + \beta_{17}H_i + e_{1i} \ , \quad (1)$$

and

$$Y_{2i} = \beta_{20} + \beta_{21}L_{21i} + \beta_{22}L_{22i} + \beta_{23}A_{2i} + \beta_{24}G_i + \beta_{25}M_i + \beta_{26}F_i + \beta_{27}Y_{1i} + e_{2i} \ . \quad (2)$$

In Equations 1 and 2, Y_{1i} and Y_{2i} are the student EOC assessment scores in 2014/2015 and 2015/2016, respectively. The three login categories were used to create two dummy-coded variables per year, where L_{11i} and L_{21i} indicate five to 30 logins in 2014/2015 and 2015/2016, L_{12i} and L_{22i} indicate more than 30 logins for the same years, and the reference category is less than five logins. For both outcomes, the model controlled for the number of absences (i.e., A_{1i} and A_{2i} in 2014/2015 and 2015/2016), gender (i.e., G_i = 1 indicates female), minority status (M_i = 1 indicates white), free/reduced lunch status (i.e., F_i =1 indicates eligible for free or reduced lunch), and Hispanic ethnicity (H_i =1 indicates Hispanic student). The model also included the 2014-2015 EOC assessment score as a predictor of the 2015-2016 score. The residuals at each year are e_{1i} and e_{2i}. The path analysis model for categories of video views and Test Yourself module answers as predictors of EOC assessment scores was defined as:

$$Y_{1i} = \gamma_{10} + \gamma_{11}V_{11i} + \gamma_{12}V_{12i} + \gamma_{13}T_{11i} + \gamma_{14}T_{12i} + \gamma_{15}A_{1i} + \gamma_{16}G_i + \gamma_{17}M_i + \gamma_{18}F_i + \gamma_{19}H_i + e_{1i} \ , \quad (3)$$

and

$$Y_{2i} = \gamma_{20} + \gamma_{21}V_{21i} + \gamma_{22}V_{22i} + \gamma_{23}T_{21i} + \gamma_{24}T_{22i} + \gamma_{15}A_{1i} + \gamma_{16}G_i + \gamma_{27}M_i + \gamma_{28}F_i + \gamma_{29}Y_{1i} + e_{2i} \ . \quad (4)$$

In Equations 3 and 4, V_{11i} and V_{21i} indicate video views, and T_{11i} and T_{21i} indicate Test Yourself module responses in the five to 30 category for 2014-2015 and 2015-2016, respectively. The variables V_{12i} and V_{22i} indicate video views, and T_{12i} and T_{22i} indicate Test Yourself module responses in the greater than 30 category for 2014-2015 and 2015-2016. The remaining variables in Equations 3 and 4 are defined as in Equations 1 and 2.

Before examining the path model parameter estimates, model fit statistics and indices were examined to determine whether the path models in Equations 1 to 4 fit the data well. We first examined the chi-square test to determine if there was exact fit, and then looked at fit indices to determine close fit based on Hu and Bentler's (1999) recommended cutoff criteria of root mean squared error of approximation (RMSEA) < .06, Tucker Lewis index (TLI) ≥ .95, Comparative Fit index (CFI) ≥ .95, and standard root mean square residual (SRMR) < .08.

To examine whether AN usage in 2015/2016 predicted passing the re-take of the EOC assessment, we used two logistic regression models. The first logistic regression model used dummy-coded login categories as predictors, while the second used dummy-coded video view and Test Yourself module response categories as predictors, controlling for the same covariates as in Equation 2 and 4. These two logistic regression models were defined as:

$$\ln\left(p_i/(1-p_i)\right) = \beta_{20} + \beta_{21}L_{21i} + \beta_{22}L_{22i} + \beta_{23}A_{2i} + \beta_{24}G_i + \beta_{25}M_i + \beta_{26}F_i + \beta_{27}Y_{1i}\ , \qquad (5)$$

and

$$\begin{aligned}\ln\left(p_i/(1-p_i)\right) = {} & \gamma_{20} + \gamma_{21}V_{21i} + \gamma_{22}V_{22i} + \gamma_{23}T_{21i} + \gamma_{24}T_{22i} + \gamma_{15}A_{1i} + \\ & \gamma_{16}G_i + \gamma_{27}M_i + \gamma_{28}F_i + \gamma_{29}Y_{1i}.\end{aligned} \qquad (6)$$

where p_i is the probability of passing the re-take of the EOC assessment in 2014/2015, and the predictors are defined as in Equations 2 and 4.

All models were estimated with the Mplus 8.1 software (Muthén & Muthén, 2017) with robust maximum likelihood estimation with cluster robust standard errors (Stapleton, 2008) to account for the clustering effects of schools. The use of cluster robust standard errors is an alternative to multilevel modeling when students are nested within classrooms and schools, and is recommended when the focus of the analysis is solely on student-level variables (McNeish, Stapleton, & Silverman, 2017). In the path analysis models, login, video view, and Test Yourself activities in 2014/2015 have an indirect effect on EOC assessment scores in 2015/2016 through the mediation of scores in 2014/2015. The standard errors for these indirect effects were calculated using the delta method (Sobel, 1982) as implemented in Mplus 8.1.

Results

Path Analysis of the Relationship Between Algebra Nation Logins and Algebra Scores

For the evaluation of fit of the path analysis model in Equations 1, the chi square test was not significant [i.e., $X^2(6, N = 3987) = 7.063$, $p = 0.315$], indicating that the model had exact fit to the data. This conclusion was supported by fit indices indicating close fit, with CFI = .997, TLI = .991, RMSEA = .007, SRMR = .004. Thus, we concluded that the first path model fit the data well, and interpreted the model parameter estimates.

Table 2 shows the standardized coefficients estimated for the first equation of the path analysis model (i.e., Equation 1), which predicts algebra scores in 2014/2015. We found that students who logged in between 5 and 30 times during 2014/2015 had EOC scores that were 0.086 standard deviation units higher on average than students with fewer than five logins, after

controlling for free/reduced lunch status, days absent, race, Hispanic origin, and gender. Table 3 shows the results for the prediction of Algebra EOC scores in 2015/2016, which corresponds to Equation 2 of the path analysis model. It shows that students who logged in between 5 and 30 times during 2015/2016 had EOC scores that were 0.093 standard deviation units higher on average than students with fewer than five logins. Also, students who logged in more than 30 times during 2015/2016 had algebra scores that were 0.195 standard deviation units higher on average than students with fewer than five logins, after controlling for covariates. Table 3 also shows that there was a significant indirect relationship between student logins in 2014/2015 and algebra scores in 2015/206, mediated by algebra scores in 2014/2015. More specifically, students who logged in between 5 and 30 times during 2014/2015 had a predicted 2015/2016 algebra score that was 0.024 standard deviations higher than those students with less than five logins.

Results in Table 2 show that students of Hispanic or Latino origin had algebra scores in 2014/2015 that were 0.147 standard deviation units lower than students not of Hispanic or Latino origin, controlling for other variables in the model. Students who were eligible for free/reduced lunch had algebra scores in 2014/2015 that were 0.179 standard deviation units lower than students who were not eligible for free/reduced lunch, controlling for other variables in the model. Also, white students had algebra scores in 2014/2015 that were 0.137 standard deviation units higher than non-white students, controlling for other variables in the model.

Table 3 shows both direct and indirect relationships of demographic variables, which can be summed to obtain a total relationship. The indirect relationships occur because some of the demographic variables have direct relationships with the 2014/2015 algebra EOC scores, which in turn has a direct relationship with 2015/2016 algebra EOC scores. In 2015/2016, students who were eligible for free/reduced lunch had algebra scores that were 0.206 (0.157 directly and 0.049

indirectly) standard deviation units lower than students who were not eligible for free/reduced lunch. Hispanic or Latino status did not have a direct relationship with 2015/2016 algebra scores, but it had an indirect relationship indicating that students of Hispanic or Latino origin were predicted to obtain scores that were on average 0.040 standard deviations lower than non-Hispanic students. White students had algebra scores in 2015/2016 that were 0.183 (0.145 directly and 0.038 indirectly) standard deviation units higher than non-white students. Gender did not have a statistically significant relationship with 2015/2016 EOC scores. The number of absences in 2015/2016 was negatively related to algebra scores, with each standard deviation increase in absences corresponding to an expected 0.051 standard deviation decrease in algebra scores.

The path analysis model in Equations 1 and 2 also revealed a significant positive relationship between 2014/2015 algebra scores and 2015/2016 algebra scores, indicating that a one standard deviation increase in scores in 2014/2015 is expected to correspond to a 0.274 standard deviation increase in 2015/2016 scores, keeping all other variables constant.

INSERT TABLES 2 AND 3 ABOUT HERE

Logistic Regression Model of the Relationship between Algebra Nation Logins and Passing Rates of Algebra EOC Assessment Re-takers

Table 4 shows the coefficients estimated with the logistic regression model with login indicators. Here we will focus on interpreting the odds for those coefficients that were

statistically significant. Positive relationships correspond to odds higher than one and indicate an increase in probability of passing the re-take of the EOC assessment. Negative relationships correspond to odds lower than one and indicate a decrease in probability of passing. In the presentation of results, we calculated 1/odds for those odds lower than 1, to present them in terms of an increase in the odds of failing the EOC assessment. The results show that students who logged in between 5 and 30 times during 2015/2016 were 1.220 times more likely to pass the EOC assessment in 2015/2016, after controlling for free/reduced lunch status, days absent, race, Hispanic origin, and gender.

The logistic regression model also revealed that for each point increase in the EOC assessment in 2014/2015, the students were expected to become 1.029 times more likely to pass the re-take of the EOC in 2015/2016, after controlling for covariates. For each absence in 2015/2016, the odds of failing the EOC in 2015/2016 was predicted to increase by 1.018 times. Students who were eligible for free/reduced lunch were 1.375 times more likely to fail the EOC in 2015/2016 than students who were not eligible for free/reduced lunch. White students were 1.362 times more likely to pass the EOC in 2015/2016 than not-white students.

INSERT TABLE 4 ABOUT HERE

Path Analysis of the Relationship of Algebra Nation Video Views and Test Yourself Module Use with Algebra scores

The path analysis model in Equations 3 and 4 had exact fit to the data, as indicated by a non-significant chi-square test [i.e., $X^2(10, N = 3987) = 10.954$, $p = 0.361$]. Also, close fit was supported by CFI = .998, TLI = .994, RMSEA = .005, and SRMR = .005. Given strong evidence that the path model fit the data well, we proceeded to interpret parameter estimates.

Table 5 shows the coefficients estimated with Equation 3 of the path analysis model, which has video views and Test Yourself module use as predictors of 2014/2015 algebra scores. The results show that students who watched between 5 and 30 videos during 2014/2015 had algebra scores that were 0.127 standard deviation units higher on average than students who watched fewer than five videos, after controlling for free/reduced lunch eligibility, days absent, race, Hispanic origin, and gender. In addition, students who watched more than 30 videos during 2014/2015 had algebra scores that were 0.126 standard deviation units higher on average than students who watched fewer than five videos. Table 5 also indicates that students who used Test Yourself module more than 30 times during 2014/2015 had algebra scores that were 0.229 standard deviation units higher on average than students who used Test Yourself module fewer than five times.

In 2014/2015, students of Hispanic or Latino origin had algebra scores that were 0.151 standard deviation units lower than students not of Hispanic or Latino origin (see Table 5). Students who were eligible for free/reduced lunch had algebra scores in 2014/2015 that were 0.176 standard deviations lower than students who were not eligible for free/reduced lunch. White students had algebra scores in 2014/2015 that were 0.136 standard deviations higher than non-white students.

Table 6 shows the estimates of the coefficients for Equation 4 of the path analysis model. The results showed no difference between students who watched fewer than 5 videos and those

who watched between 5 and 30 videos in 2015/2016 on algebra scores, but it showed an indirect relationship between watching 5 to 30 videos in 2014/2015 and the 2015/2016 algebra scores. Specifically, students who watched between 5 and 30 videos in 2014/2015 had algebra scores in 2015/2016 that were 0.035 standard deviations higher than the group watching less than five videos. Also, students who watched more than 30 videos during 2015/2016 had algebra scores that were 0.176 standard deviation units higher on average than students who watched fewer than five videos. Students who watched more than 30 videos in 2014/2015 had mean score in the 2015/2016 assessment that was 0.034 standard deviations higher than students who watched fewer than 5 videos, through the mediation of the 2014/2015 algebra score.

The results presented in Table 6 indicate that students who used the Test Yourself tool between 5 and 30 times during 2015/2016 had algebra scores that were 0.140 standard deviation units higher on average than students who watched fewer than five videos. Students who used the Test Yourself module more than 30 times in 2015/2016 had EOC scores that were 0.185 standard deviation units higher on average than students who used the Test Yourself module fewer than five times. Also, students who used the Test Yourself module more than 30 times in 2014/2015 had a higher mean algebra score in 2015/2016 by 0.062 standard deviations.

As shown in Table 6, the model also revealed that a one standard deviation increase in algebra scores in 2014/2015 corresponded to a 0.273 standard deviation increase in scores on the 2015/2016 EOC assessment retake, keeping all other variables constant. Furthermore, for each one standard deviation increase in student absences in 2015/2016, algebra scores were predicted to decrease by 0.051 standard deviations. Students of Hispanic or Latino origin had algebra scores in 2015/2016 that were 0.041 (indirectly) standard deviation units lower than students not of Hispanic or Latino origin, through the mediation of 2014/2015 EOC scores. Students eligible

for free/reduced lunch had scores in 2015/2016 that were 0.200 (0.152 directly and 0.048 indirectly) standard deviation units lower than students who were not eligible for free/reduced lunch. White students had scores in 2015/2016 that were on average 0.176 (0.139 directly and 0.037 indirectly) standard deviation units higher than non-white students. There were no differences between males and females in algebra scores in 2015/2016.

INSERT TABLE 5 AND 6 ABOUT HERE

Logistic Regression Model of the Relationship of Algebra Nation Video Views and Test-Yourself Use with Passing Rates of EOC Assessment Re-takers

Table 7 shows the coefficients estimated with the logistic regression model with video views and Test Yourself module responses indicators. We will interpret the odds of the variables found to be statistically significant, inverting the negative odds. We found that students who used the Test Yourself module between 5 and 30 times during 2015/2016 were 1.590 times more likely to pass the EOC assessment in 2015/2016 than students who used Test Yourself less than five times, after controlling for algebra scores in 2014/2015, free/reduced lunch eligibility, days absent, race, Hispanic origin, and gender. Video views were not related to increases in the odds of passing the EOC assessment. The model also revealed that for each point increase in scores in 2014/2015, students were 1.029 times more likely to pass the 2015/2016 EOC assessment. For each absence a student had in 2015/2016, the student was 1.018 times more likely to fail the assessment. Students who were eligible for free/reduced lunch were 1.342 times more likely to fail the EOC in

2015/2016 than students who were not eligible for free/reduced lunch. White students were 1.343 times more likely to pass the EOC assessment in 2015/2016 than not-white students.

INSERT TABLE 7 ABOUT HERE

Discussion and Conclusion

Both the logins model and the video views and Test Yourself tool models indicated that in the 2014/2015 school year, students who used AN more were predicted to score higher on the EOC assessment than less-frequent users, even though they did not achieve a passing score on their first attempt (Research Question 1). However, the effects of logins were not consistent across the login groups, because students having between 5 and 30 logins had higher scores than students with fewer logins, but students with more than 30 logins did not (see Table 2). This inconsistency may be due to differences in power levels, because the group with more than 30 logins is substantially smaller than the group with between 5 and 30 logins (see Table 1). For video views, the coefficients of the group with between 5 and 30 video views and the group with more than 30 video views are similar. For Test Yourself module responses, the effect was not significant for the group with between 5 and 30 uses but was significant for the group of more than 30 uses (see Table 5), indicating a pattern of increase in Algebra EOC scores as the number of Test Yourself module responses increases.

In the next year (i.e., 2015/2016), the students who had failed the EOC assessment and were now preparing to re-take it and had more frequent AN use achieved higher scores than

comparable students with lower use (Research Question 2). There was a consistent increase in total effects (i.e., sum of direct and indirect effects shown in Table 3) from the students group with between 5 and 30 logins to the student group with more than 30 logins. With respect to video views and test yourself module, there was also a consistent increase in total effects from the group with between 5 and 30 uses from the group with more than 30 uses (see Table 6).

AN usage predicted an increase in students' scores from the previous year. Using AN more than 30 times in both 2014/2015 and 2015/2016 school years was associated with a more successful EOC retake outcome. The positive relationship was observed for two types of Algebra Nation usage: overall frequency of logging in, and using specific resources such as viewing instructional videos and completing practice problems. With regard to the activities within the AN platform that appeared to be most helpful (Research Question 3), there was some indication that higher use of the Test Yourself module in which students practiced solving problems similar to those that they would encounter on the actual exam had more impact than viewing instructional videos, because the standardized coefficients were larger by some extent (see Table 6). Furthermore, in the logistic regression shown in Table 7, Test Yourself responses were related to increased odds of passing the exams, while video views were not. This is consistent with prior work showing that interactive online activities are more strongly linked with improved learning outcomes than viewing videos or reading text (Koedinger et al., 2015, 2016). Also, as OERs afford environments that require students' use of self-regulatory strategies, the finding that use of the Test Yourself module is most strongly related to student achievement is consistent with self-regulated learning theory (Panke & Seufert, 2013, Kim, Lee, Park, in press).

The analyses also indicated that performance on the EOC assessment was related to student characteristics. More specifically, not-white students, those of Hispanic background, and

those eligible for free/reduced lunch tended to have lower scores. Performance was also related to student behavior with respect to school attendance. Not surprisingly, more frequent school absence was associated with lower algebra scores. These patterns are generally consistent with other work on risk factors associated with algebra performance (Snipes & Finkelstein, 2015).

The results indicate that struggling students with higher usage of AN scored better on the EOC assessment than comparable students with less (and very little) AN use. This pattern was apparent in both school years. Students with higher level of usage of AN were also more likely to achieve a passing score the following year. The results of this study show evidence of promise of AN as an OER to help struggling students learn algebra. Because OER characteristics and how they are used by students vary widely (Olcott Jr., 2012), it is necessary to connect the mechanisms associated with OER use to a specific theory of learning and cognition (Panke & Seufert, 2013) to predict how the results obtained with AN in this study may generalize to other OERs. For example, from a self-regulated learning perspective, it is expected that OERs such as AN will benefit the most students who are effective self-regulators, and the relationship between OER use and student achievement would replicate for OER that facilitate self-regulated learning. Kim, Lee and Park (in press) used data from several OER in the OER hub project to classify students according to self-regulated learning strategies. They found four classes that differed with respect to their extent of engagement with social and individual self-regulated learning strategies, but did not examine their relationships between these classes and learning outcomes. The current study provides a contribution by linking a specific self-regulated learning strategy (i.e. answer questions in the Test Yourself module) to student achievement. Future research is needed to connect a variety of types of self-regulated use of OER to student achievement.

This study contributes to the body of evidence about effects of OER student use on high-stakes educational outcome. However, the conclusions of this study are subject to the following limitations: Because the current study was not an experimental design that manipulated availability of videos and the Test Yourself module randomly and independently, conclusions about relative effectiveness of these AN activities are preliminary. Therefore, additional studies are needed to obtain stronger evidence for the "do-er effect, to understand which self-regulated learning strategies in AN are related to student achievement, and to design strategies that optimize self-regulated learning in AN. Experimental and quasi-experimental studies are necessary because it is possible that students who used AN more often did so for reasons that might have contributed to their higher algebra scores, such as they may have been more motivated to pass the EOC assessment, they may have had more encouragement from teachers or parents, and/or they may have had better guidance about how to use the site effectively. However, correlational studies form a necessary foundation to justify and encourage future research on effectiveness claims (Institute of Education Sciences, U.S. Department of Education, and National Science Foundation, 2013), and our study serves this important purpose. Additionally, the analysis focused on the population of students who had already failed and who were targeted because they were very likely to fail again. The sample included only students who had used Algebra Nation at least once because data was not available on non-users. Given the motivational and learning challenges associated with these students, it is striking that there was any detectable relationships between achievement and AN use. Also, for most students the difference was not substantial; indeed, for the majority, the improvement was not enough to ensure a passing score. The overall passing rate of this sample when they re-took the EOC assessment was 9.5%. The effect sizes found in this study are consistent with prior work

indicating that relatively small effect sizes are expected with the use of standardized test scores as the outcome measure (Cheung & Slavin, 2013).

Another limitation is that the study did examine other ways that students may have prepared for re-taking the EOC assessment besides AN, such as enrollment in a credit recovery course. However, not all students who fail the EOC assessment can retake the entire algebra course, and even if they could, doing so would mean a lost opportunity to take a different course. Also, enrolling all algebra re-takers into algebra courses would likely be an unsustainable burden on the education system in most states. The rapid adoption of the AN platform within the state suggests that struggling students and their teachers were actively seeking a resource that might be helpful and that these stakeholders are willing to consider an alternative route to teaching struggling students.

The present results converge with previous work in suggesting the potential value of open education resources. The next question is to identify how such resources can be most effectively used (Lowes & Lin, 2017). As a result of implementation research that established what elements teachers most valued and prompted changes to the platform, Khan Academy ultimately transitioned from an OER to being a formal part of the curriculum in a number of states and districts (Heppen et al., 2006; Phillips & Cohen, 2015). Similarly, in the case of AN, additional experimental research is needed to pinpoint factors such as the optimum frequency of use and the appropriate balance of activities such as watching instructional videos relative to doing practice problems as well as to determine its potential value for all students taking algebra, not only those who have a history of failure. The present study provided the necessary correlational foundations for this future intervention development work (Institute of Education Sciences, U.S. Department of Education, and National Science Foundation, 2013).

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Table 1

Sample sizes of groups included in the analysis

		Sample size 2014/2015	Sample size 2015/2016
Logins	less than 5 times	1442	2069
	between 5 and 30 times	2104	1720
	more than 30 times	441	198
Video views	less than 5 times	1823	2300
	between 5 and 30 times	1502	1263
	more than 30 times	662	424
Test-yourself tool responses	less than 5 times	3393	3527
	between 5 and 30 times	507	374
	more than 30 times	87	86
Gender	Female students	2209	2209
	Male students	1778	1778
Race	White students	2065	2065
	Non-white students	1922	1922
Ethnicity	Hispanic/Latino origin	1267	1267
	Non-Hispanic/Latino origin	2720	2720
Reduced/free lunch	Eligible	3141	3141
	Not Eligible	846	846

Table 2

Standardized Parameter estimates for path analysis model for the relationship between Algebra Nation Logins and Algebra I End-of-Course Assessment Scores in 2014/2015

Outcome: Algebra EOC Scores 2014/2015	*Estimate*	*S.E.*	*P-Value*
Intercept	**22.014**	0.283	0.000***
Between 5 and 30 logins	**0.086**	0.037	0.018*
More than 30 logins	0.071	0.055	0.195
Days Absent	-0.023	0.014	0.103
Eligible for free/reduced lunch	**-0.179**	0.039	0.000***
Hispanic/Latino origin	**-0.147**	0.041	0.000***
White student	**0.137**	0.038	0.000***
Female student	0.045	0.032	0.156
Residual Variance	**0.985**	0.004	0.000***

Note. Statistically significant coefficients are in bold. Significant codes: *** 0.001; ** 0.01; * 0.05.

Table 3

Standardized Parameter estimates for path analysis model for the relationship between Algebra Nation Logins and Algebra I End-of-Course Assessment Scores in 2015/2016

Outcome: Algebra EOC Scores 2015/2016	*Relationship type*	*Estimate*	*S.E.*	*P-Value*
Intercept		**16.638**	0.500	0.000***
Algebra EOC Scores 2014/2015	Direct	**0.274**	0.014	0.000***
Between 5 and 30 logins 2015/2016	Direct	**0.093**	0.032	0.004***
Between 5 and 30 logins 2014/2015	Indirect	**0.024**	0.010	0.020*
More than 30 logins 2015/2016	Direct	**0.195**	0.076	0.010**
More than 30 logins 2014/2015	Indirect	0.019	0.015	0.195
Days Absent 2015/2016	Direct	**-0.051**	0.016	0.002***
Days Absent 2014/2015	Indirect	-0.001	0.000	0.106
Eligible for free/reduced lunch	Direct	**-0.157**	0.042	0.000***
	Indirect	**-0.049**	0.011	0.000***
Hispanic/Latino origin	Direct	-0.002	0.037	0.948
	Indirect	**-0.040**	0.012	0.001***
White student	Direct	**0.145**	0.037	0.000***
	Indirect	**0.038**	0.010	0.000***
Female student	Direct	-0.002	0.036	0.952
	Indirect	0.012	0.009	0.157
Residual Variance		**0.903**	0.010	0.000***

Note. Indirect relationships are mediated by 2014/2015 algebra EOC Scores; Statistically significant coefficients are in bold. Significant codes: *** 0.001; ** 0.01; * 0.05.

Table 4

Standardized Parameter estimates for Logistic Regression model for the relationship between Algebra Nation Logins and Algebra I End-of-Course Assessment Passing Rates in 2015/2016

Predictor	Estimate	S.E.	P-Value	Odds of passing
Algebra EOC Scores 2014/2015	**0.015**	0.001	0.000***	1.029
Between 5 and 30 AN logins	**0.102**	0.045	0.021**	1.220
More than 30 logins	0.172	0.108	0.112	1.398
Days Absent	**-0.009**	0.003	0.004**	0.982
Eligible for free/reduced lunch	**-0.164**	0.056	0.003**	0.727
Hispanic/Latino origin	0.059	0.054	0.280	1.121
White student	**0.159**	0.057	0.005**	1.362
Female student	-0.026	0.045	0.575	0.952

Note. Statistically significant coefficients are in bold. Significant codes: *** 0.001; ** 0.01; * 0.05.

Table 5

Standardized Parameter estimates for path analysis model for the relationships between Algebra Nation Video Views, Test Yourself Module Responses, and Algebra EOC Scores in 2014/2015

Outcome: Algebra EOC Scores 2014/2015	*Estimate*	*S.E.*	*P-Value*
Intercept	21.981	0.281	0.000***
Between 5 and 30 video views	**0.127**	0.039	0.001***
Between 5 and 30 Test Yourself module responses	0.059	0.053	0.263
More than 30 video views	**0.126**	0.050	0.012*
More than 30 Test Yourself module responses	**0.229**	0.090	0.011*
Days Absent	-0.018	0.014	0.212
Eligible for free/reduced lunch	**-0.176**	0.039	0.000***
Hispanic/Latino origin	**-0.151**	0.041	0.000***
White student	**0.136**	0.038	0.000***
Female Student	0.044	0.032	0.166
Residual Variance	0.980	0.005	0.000***

Note. Statistically significant coefficients are in bold. Significant codes: *** 0.001; ** 0.01; * 0.05.

Table 6

Standardized Parameter estimates for path analysis model for the relationships between Algebra Nation Video Views, Test Yourself Module Responses, and Algebra EOC Scores in 2015/2016

Outcome: Algebra EOC Scores 2015/2016	*Relationship type*	*Estimate*	*S.E.*	*P-Value*
Intercept		16.659	0.503	0.000***
Algebra EOC Scores 2014/2015	Direct	**0.273**	0.014	0.000***
Between 5 and 30 video views 2015/2016	Direct	0.027	0.038	0.473
Between 5 and 30 video views 2014/2015	Indirect	**0.035**	0.011	0.001***
Between 5 and 30 Test Yourself module responses 2015/2016	Direct	**0.140**	0.061	0.022*
Between 5 and 30 Test Yourself module responses 2014/2015	Indirect	0.016	0.014	0.264
More than 30 video views 2015/2016	Direct	**0.176**	0.054	0.001***
More than 30 video views 2014/2015	Indirect	**0.034**	0.014	0.013*
More than 30 Test Yourself module responses 2015/2016	Direct	**0.185**	0.076	0.014*
More than 30 Test Yourself module responses 2014/2015	Indirect	**0.062**	0.024	0.011*
Days Absent 2015/2016	Direct	**-0.051**	0.016	0.002***
Days Absent 2014/2015	Indirect	-0.005	0.004	0.215
Eligible for free/reduced lunch	Direct	**-0.152**	0.042	0.000***
	Indirect	**-0.048**	0.011	0.000

Hispanic/Latino origin	Direct	-0.002	0.037	0.950
	Indirect	**-0.041**	0.012	0.000***
White student	Direct	**0.139**	0.036	0.000***
	Indirect	**0.037**	0.010	0.000***
Female Student	Direct	-0.007	0.037	0.857
	Indirect	0.012	0.009	0.168
Residual Variance		0.901	0.010	0.000***

Note. Indirect relationships are mediated by 2014/2015 algebra EOC Scores; Statistically significant coefficients are in bold; Significant codes: *** 0.001; ** 0.01; * 0.05.

Table 7

Standardized parameter estimates for Logistic Regression model for the relationship between Algebra Nation Video views and use of Test-yourself module and Algebra I End-of-Course Assessment Passing Rates in 2015/2016

Predictor	Estimate	S.E.	P-Value	Odds of passing
EOC Scores 2014/2015	**0.029**	0.003	0.000***	1.029
Between 5 and 30 video views	0.038	0.095	0.691	1.038
Between 5 and 30 Test Yourself module responses	**0.464**	0.145	0.001***	1.590
More than 30 video views	0.221	0.132	0.094	1.247
More than 30 Test Yourself module responses	0.157	0.305	0.607	1.170
Days Absent	**-0.018**	0.006	0.004**	0.982
Eligible for free/reduced lunch	**-0.295**	0.110	0.007**	0.745
Hispanic/Latino origin	0.113	0.105	0.284	1.119
White student	**0.295**	0.110	0.007**	1.343
Female Student	-0.060	0.089	0.500	0.942

Note. Statistically significant coefficients are in bold. Significant codes: *** 0.001; ** 0.01; * 0.05.

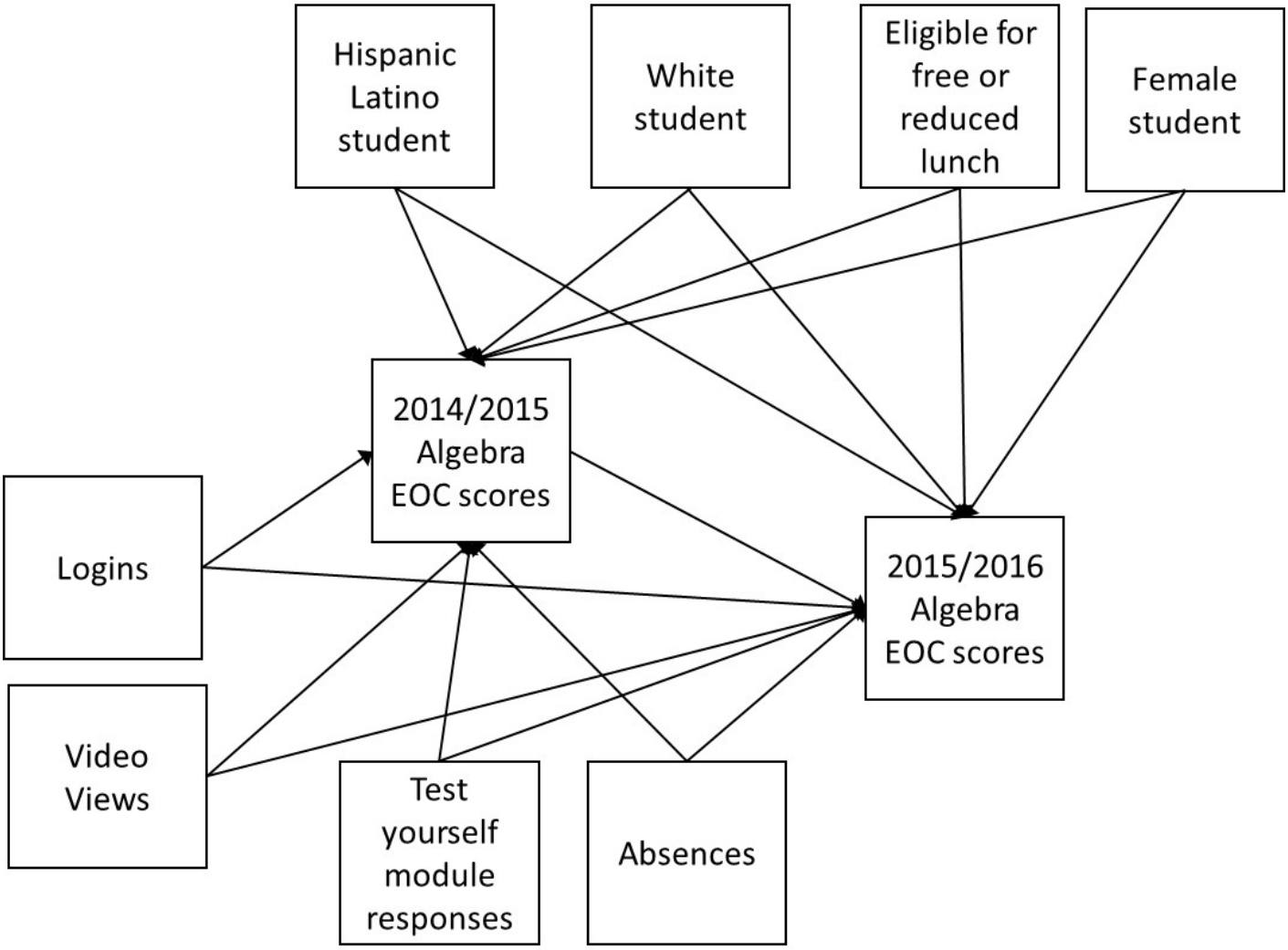

Figure 1. Conceptual representation of the hypothesized relationships between Algebra Nation usage and Algebra I End-of-Course assessment scores